AF/1753

IFW

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
Before the Board of Patent Appeals and Interferences

In re Patent Application of

ROHR et al

Serial No. 09/955,297

Filed: September 19, 2001

Title: PHOTOVOLTAIC DEVICE

Atty Dkt. 550-269

C# M#

TC/A.U.: 1753

Examiner: Brian Mutschler

Date: July 12, 2004

OIPE JCG7 JUL 1 2 2004 PATENT & TRADEMARK OFFICE

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

☐ **Correspondence Address Indication Form Attached.**

☐ **NOTICE OF APPEAL**
Applicant hereby **appeals** to the Board of Patent Appeals and Interferences from the last decision of the Examiner. ($ 330.00) $

☒ An appeal **BRIEF** is attached in triplicate in the pending appeal of the above-identified application ($ 330.00) $ 330.00

☐ Credit for fees paid in prior appeal without decision on merits -$ ( )

☐ A reply brief is attached in triplicate under Rule 193(b) **(no fee)**

☐ Petition is hereby made to extend the current due date so as to cover the filing date of this paper and attachment(s) **($110.00/1 month**; $420.00/2 months; **$950.00/3 months**; $1480.00/4 months) $

SUBTOTAL $ 330.00

☐ Applicant claims "Small entity" status, enter ½ of subtotal and subtract -$( )
☐ "Small entity" statement attached.

SUBTOTAL $ 330.00

Less month extension previously paid on -$(0.00)

TOTAL FEE ENCLOSED $ 330.00

Any future submission requiring an extension of time is hereby stated to include a petition for such time extension. The Commissioner is hereby authorized to charge any deficiency, or credit any overpayment, in the fee(s) filed, or asserted to be filed, or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our **Account No. 14-1140.** A duplicate copy of this sheet is attached.

1100 North Glebe Road, 8th Floor
Arlington, Virginia 22201-4714
Telephone: (703) 816-4000
Facsimile: (703) 816-4100
SCS:kmm

NIXON & VANDERHYE P.C.
By Atty: Stanley C. Spooner, Reg. No. 27,393

Signature: ______________________

861863

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Patent Application of

ROHR et al — Atty. Ref.: 550-269

Serial No. 09/955,297 — Group: 1753

Filed: September 19, 2001 — Examiner: Brian Mutschler

For: PHOTOVOLTAIC DEVICE

* *

APPEAL BRIEF

On Appeal From Group Art Unit 1753

Stanley C. Spooner
NIXON & VANDERHYE P.C.
8th Floor, 1100 North Glebe Road
Arlington, Virginia 22201-4714
(703) 816-4028
Attorney for Appellant

861773

TABLE OF CONTENTS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Patent Application of

ROHR et al | Atty. Ref.: 550-269

Serial No. 09/955,297 | Group: 1753

Filed: September 19, 2001 | Examiner: Brian Mutschler

For: PHOTOVOLTAIC DEVICE

* *

July 12, 2004

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

APPEAL BRIEF

Sir:

I. REAL PARTY IN INTEREST

The real party in interest in the above-identified appeal is Imperial College of Science, Technology and Medicine in London, England, by virtue of the Assignment from the inventors to the Imperial College recorded January 16, 2002 at Reel 12491, Frame 144.

II. RELATED APPEALS AND INTERFERENCES

There are believed to be no related appeals or interferences with respect to the present application and appeal.

III. STATUS OF CLAIMS

Claims 1-18, 20-27, 31-33 and 35-38 stand rejected in the outstanding Final Rejection. The Examiner contends that these claims are either anticipated under 35 USC §102 or obvious under 35 USC §103 in view of the cited prior art.

IV. STATUS OF AMENDMENTS

No further response has been submitted with respect to the Final Official Action in this application.

V. SUMMARY OF THE INVENTION

The present invention relates to photovoltaic devices and in particular an improved photovoltaic cell for the conversion of heat radiation into electricity. Thermovoltaics (TPV) is the use of a photovoltaic (PV) cell to convert heat radiation into electricity. Higher efficiencies can normally be achieved by introducing multi-quantum-wells (MQW) into the intrinsic region of a p-i-n diode if the gain in short-circuit current exceeds the loss in open-circuit voltage.

Prior to the present invention, there was considerable interest in extending the absorption to longer wavelengths in order to improve overall system efficiencies. Because appropriate and inexpensive substrates of the required lattice constant and bandgap are not available, a lower bandgap material is often strained to the substrate introducing dislocations which reduce the efficiency of

the device. Freundlich, in U.S. Patent 5,851,310 and U.S. Patent 6,150,604, recognized the problem of such dislocations and suggested limiting the number of wells to a maximum of 20 in order to avoid degrading the conversion efficiency. However, the difficulty with this approach is that a maximum of 20 wells will not produce sufficient absorption for the most efficient generation.

A number of the current inventors, in an article entitled "Strain-balanced GaAsP/InGaAs quantum well solar cells" in December of 1999 (Ekins-Daukes I), suggested that if the average lattice strain parameter for all of the plurality of barriers can be matched to the strain in the substrates, then this "strain-balanced" approach could improve the efficiency of the solar cell. Ekins-Daukes I taught that dimensions of the compressive strain layers and the tensile strain layers "were chosen to ensure the **average lattice parameter** across the *i* region (a) was equal to that of GaAs." (emphasis added).

While this was a desirable result, the teaching of how to achieve this desirable result was insufficiently exact (as set out in the Rule 132 Declaration of independent expert, Dr. Neal Anderson, paragraph 12) to ensure that the individual periods (one compressively strained layer and one tensilely strained layer) exert substantially no shear force on a neighboring structure. This fact has not been rebutted by any evidence of record in this application. Thus, the overall approach in Ekins-Daukes I was correct, but the manner in which the desirable result could be achieved in a photovoltaic device was as yet unrecognized.

After publishing the Ekins-Daukes 1 reference, the present inventors continued to work on the problem, i.e., lattice mismatch placing an upper limit on the number of quantum wells that can be accommodated before strain relaxation takes place, thereby compromising the obtainable open circuit voltage. They found that, if the quantum wells and the barriers in the photovoltaic device had compositions such that in one period the tensile strained layer and the compressively strained layer exerted substantially no shear force on a neighboring structure, then the specific interrelationship suggested in Ekins-Daukes I could be achieved providing the desired improved conversion efficiency.

Therefore, the present invention is characterized by a plurality of quantum wells and a plurality of barriers, where the barriers alternate with the quantum wells. One of the quantum wells and barriers is comprised of a tensile strained layer and the other of the quantum wells and barriers is comprised of compressively strained layers. Compositions, dimensions and other aspects of these layers are such that **"a period of one tensile strained layer and one compressively strained layer exerts substantially no shear force on a neighbouring structure."**

VI. ISSUES

Whether claims 1-6, 12, 13, 42 and 43 are anticipated by Ekins-Daukes I.

Whether claims 7-11, 14 and 15 are obvious over Ekins-Daukes I in view of Freundlich '310.

Whether claims 16 and 17 are obvious over Ekins-Daukes I in view of Freundlich '604.

Whether claims 18 and 20-27 are obvious in view of Freundlich '310 in view of Ekins-Daukes I.

Whether claims 31 and 32 are unpatentable over Freundlich '310 in view of Ekins-Daukes I.

Whether claims 33 and 35-41 are unpatentable over Freundlich '310 in view of Ekins-Daukes I and Freundlich '604.

Whether claims 44-47, 53 and 54 are unpatentable as being obvious in view of Ekins-Daukes I.

Whether claims 48-52, 55 and 56 are unpatentable as obvious in view of Ekins-Daukes I in view of Freundlich '310.

Whether claims 57 and 58 are unpatentable under 35 USC §103 over Ekins-Daukes I in view of Freundlich '604.

VII. GROUPING OF CLAIMS

The rejected claims stand or fall as being based upon the independent claims 1, 18, 33 and 44.

VIII. ARGUMENT

1. Discussion of the References

Ekins-Daukes I ("Strain-balanced GaAsP/InGaAs quantum well solar cells" published December 27, 1999, *Applied Physics Letters*) discloses and discusses the problem of lattice mismatches placing an upper limit on the number of quantum wells that can be accommodated before compromising the open circuit voltage of a solar cell. To solve the problem, Ekins-Daukes suggests a "strain-balance approach," but also indicates that in order to implement this approach, it is only necessary to ensure that "the average lattice parameter" be strain balanced. In other words, Ekins-Daukes teaches that it is only necessary that the average strain for all quantum wells and barriers be adjusted to the substrate and provides formulas in which values can be chosen so as to minimize the average strain.

There is no recognition in Ekins-Daukes that the overall average strain is not as important as the strain of each period and that each period exerts substantially no shear force on a neighboring period.

Freundlich '310 (U.S. Patent 5,851,310) teaches the well-known combination of elements providing "quantum wells" to the intrinsic region (undoped) of p-i-n solar cells, where a "quantum well" is defined as a heterostructure comprised of two or more semiconductor materials having

different bandgaps. Freundlich '310 also discloses that improved conversion efficiencies can be achieved by a plurality of quantum wells.

There is no disclosure in Freundlich '310 that there is any benefit to choosing quantum wells and barriers such that a period comprised of one tensile strained layer and one compressively strained layer exerts substantially no shear force on a neighboring structure.

Freundlich '604 (U.S. Patent 6,150,604) is a continuation-in-part of Freundlich '310 and specifically discusses thermovoltaic cells. As noted in the summary of the invention, Freundlich '604 suggests that there is a maximum limit of approximately 20 periods in such cells and going beyond this limit results in too many dislocations to maintain desired current output.

Again, there is no disclosure of the matching of tensile and compressively strained layers in a period such that "substantially no shear force on a neighboring structure" is applied.

2. Discussion of the Rejections

Claims 1-6, 12, 13, 42 and 43 stand rejected as being anticipated by Ekins-Daukes I. To the extent the Examiner's rejection is understood, the Examiner appears to believe that because Ekins-Daukes I teaches the desirability of each period exerting substantially no shear force on a neighboring structure, that this teaches Appellants' claim. However, when asked to indicate where or how the

Ekins-Daukes I reference teaches Appellants' claim, the Examiner failed to point to any disclosure in the Ekins-Daukes I reference which suggests that this is accomplished or would teach one of ordinary skill in the art how to accomplish this result. While Ekins-Daukes I teaches that the average strain is a "negligible quantity," this does not suggest that strain between a period and neighboring structures have been minimized to "substantially no shear force."

Claims 7-11, 14 and 15 stand rejected under 35 USC §103 as unpatentable over Ekins-Daukes I in view of Freundlich '310. To the extent it is understood, the Examiner appears to apply Ekins-Daukes I in the manner of the rejection under 35 USC §102, but admits that Ekins-Daukes I does not disclose seven aspects recited in claims 7, 8, 9, 10, 11, 14 and 15 noted on page 5 of the Final Rejection.

Even though Ekins-Daukes I does not relate to a strain-balance approach for enhancing solar cell efficiency, the Examiner nevertheless is apparently of the opinion that because both Ekins-Daukes I and Freundlich '310 provide beneficial results, that it would somehow be obvious to combine them. There is no disclosure, however, in the Final Rejection as to where or how one of ordinary skill in the art would be motivated to combine these two references or even if they could be combined.

Claims 16 and 17 stand rejected under 35 USC §103 as unpatentable over Ekins-Daukes I in view of Freundlich '604. The Examiner admits that Ekins-Daukes I "does not disclose that the device is a thermophotovoltatic device and

that the quantum wells have a bandgap equal to or less than 0.73 eV." Again, the Examiner is apparently applying Ekins-Daukes I as in the rejection under 35 USC §102 and then believes that Freundlich '604 not only teaches the admittedly missing disclosure. Presumably, the Examiner believes that there is some reason for combining the Ekins-Daukes I reference and the Freundlich '604 reference. However, the reason for combining these references is not apparent to the reader of the Final Rejection.

Claims 18 and 20-27 stand rejected as unpatentable over Freundlich '310 in view of Ekins-Daukes I. Independent claim 18 and claims 20-27 dependent thereon are alleged to be disclosed over Freundlich '310 as the primary reference, with the Ekins-Daukes I reference providing the additional missing information from Freundlich. The Examiner admits on page 10 that Freundlich '310 does not have at least four elements recited in claims 18, 20 and 24. The Examiner appears to be of the opinion that the missing teaching of strain balancing is taught in the Ekins-Daukes I reference. However, the Examiner has not provided any indication of how or where Ekins-Daukes I provides a teaching of how the theoretical benefit of Ekins-Daukes I is to be achieved or why there would be any reason to combine Ekins-Daukes I with the Freundlich '310 disclosure.

Claims 31 and 32 stand rejected under 35 USC §103 as unpatentable over Freundlich '310 in view of Ekins-Daukes I in further view of Freundlich '604. The Examiner admits that Freundlich '310 and Ekins-Daukes I do not disclose

limitations recited in claims 31 and 32. However, the Examiner appears to believe that it would be obvious for one of ordinary skill in the art to combine the disclosures in Freundlich '310, Freundlich '604 and Ekins-Daukes I. There is no apparent motivation for such combination discussed in the Official Action.

Claims 33 and 35-41 stand rejected under 35 USC §103 as unpatentable over Freundlich '310 in view of Ekins-Daukes I and Freundlich '604. Again, the Examiner appears to have reshuffled his mosaic of references which he believes allegedly disclose all of the claims in this application. The Examiner admits that Freundlich '310 fails to teach six elements recited in claims 33, 35, 39, 40 and 41. While the Examiner appears to believe that it would be obvious to combine elements of Freundlich '310, Freundlich '604 and the Ekins-Daukes reference, there appears to be no motivation for such combination suggested in the Official Action.

Claims 44-47, 53 and 54 stand rejected under 35 USC §103 as unpatentable over Ekins-Daukes I. The Examiner is apparently of the belief that Ekins-Daukes I teaches that the average strain is negligible and that the strain across one period is a function of the thickness in material properties of each layer. These contentions are absolutely correct. However, as noted above, Ekins-Daukes I does not suggest how to ensure that the strain in each period exerts substantially no shear force on a neighboring structure. While it may suggest the desirability of this approach, there is no teaching of how this can be achieved in the Ekins-

Daukes I reference. The Examiner appears to believe that if the benefit is disclosed, then all possible combinations of elements or configurations which will achieve that benefit are somehow rendered obvious. To the extent it is understood, the Examiner's rationale is not believed to be correct.

Claims 48-52, 55 and 56 stand rejected under 35 USC §103 as unpatentable over Ekins-Daukes I as previously applied to claim 44 in view of Freundlich '310. The Examiner admits that Ekins-Daukes I does not disclose seven structures recited in the claims dependent from claim 44, but suggests that these are somehow disclosed or rendered obvious in view of the Freundlich '310 reference. Again, there is no disclosure as to how or why one of ordinary skill in the art would be motivated to combine elements from the various references.

Claims 57 and 58 stand rejected under 35 USC §103 as unpatentable over Ekins-Daukes I in view of Freundlich '604. The Examiner admits that Ekins-Daukes I does not teach the aspects of claims 57 and 58, but suggests that Freundlich '604 does contain such teaching. The Examiner does not indicate how or why one of ordinary skill in the art would be motivated to combine the Ekins-Daukes and Freundlich '604 references.

3. The Errors in the Final Rejection

There are at least four significant errors in the Final Rejection and they are summarized as follows:

(a) No prior art reference teaches that in order to create an efficient photovoltaic device, it is necessary that the composition of the strained layers be such that each period "exerts substantially no shear force on a neighbouring structure;"

(b) Ekins-Daukes I teaches that the average for all periods must be minimized, but not that each period should exert "substantially no shear force on a neighbouring structure;" and

(c) Freundlich '310 and '604, in suggesting limiting to 20 periods, teach away from the claimed invention.

(d) There is no reason or motivation for combining any of the prior art references.

(a) No prior art reference teaches that in order to create an efficient photovoltaic device, it is necessary that the composition of the strained layers be such that each period "exerts substantially no shear force on a neighbouring structure"

The Freundlich '310 and '604 references, as admitted by the Examiner, do not teach any sort of strain balancing construction. Only the Ekins-Daukes I reference teaches that it is beneficial to use a strain-balanced approach for enhancing solar cell efficiency. The Examiner correctly notes that Ekins-Daukes I suggests that there is a benefit if the average lattice parameter across the intrinsic region was equal to the substrate (thereby resulting in minimized dislocations).

The Ekins-Daukes I reference discloses that the following of Equations 1 and 2 yields an average strain which provides a negligible quantity for a layer 1 μm thick. Inasmuch as the 1 μm layer has a plurality of periods (20 in the Example discussed in Ekins-Daukes I), the negligible quantity of strain is for the entire 20-period layer, i.e., "the average lattice parameter" across the entire 20-period layer.

As noted above, the present inventors found that while Ekins-Daukes I recognizes that it is desirable to reduce the strain to a negligible quantity, there is no teaching that this can be done by ensuring that each period exerts "substantially no shear force on a neighbouring structure."

The difference between what is taught in Ekins-Daukes 1 and in the present invention can perhaps be best understood by assuming there be a series of 20 periods in a layer, with the first period having an average strain of +4 and the next period having a strain of -4, alternating so on through the entire 20-period layer. There will be 10 periods having a +4 strain and 10 periods having a -4 strain. As a result, the average strain over the 20-period layer will be zero, which certainly is a "negligible quantity" for the layer.

However, Appellants' claim recites that for each "period of one tensile strained layer and one compressively strained layer," that period "exerts substantially no shear force on a neighbouring structure." In the above example taught in the Ekins-Daukes I reference, with one period having a +4 strain and the adjacent period having a -4 strain, there is a total of an 8-unit strain between each

neighboring period. Appellants' independent claims 1, 18, 33 and 44 all require that there be substantially no shear force between one period and "a neighbouring structure." Thus, in Appellants' embodiment, all 20 periods would have "substantially no shear force" on their neighboring structures, i.e., each one would be about zero. While this then would also provide the total strain for the 20-period layer being essentially zero as taught in Ekins-Daukes I, but the additional requirement that there be substantially no shear force between each period and its neighboring structure, is not taught or rendered obvious by the Ekins-Daukes I reference.

While Appellants have repeatedly questioned the Examiner on the point of where Ekins-Daukes I suggests that each period "exert substantially no shear force on a neighboring structure," the Examiner has either failed to understand or appreciate this claim requirement or has ignored it in each Official Action. While it is hopeful that the above explanation will clarify Appellants' claim language, should the Examiner be of the opinion that this is shown somewhere in the Ekins-Daukes I reference, he is respectfully requested to identify such disclosure.

While the Examiner has suggested that Appellants may wish to claim the present invention as a method for making a photovoltaic device, Appellants note that there may be many methods of creating periods which exert "substantially no shear force on a neighbouring structure." Applicant does not wish the claims to the specific photovoltaic device to be limited by the manner in which those

individual periods are created. It is noted that the limitation "exerts substantially no shear force on a neighbouring structure" is a structural interrelationship limitation and is not a method step limitation.

Accordingly, absent the Patent Office being able to point out how or where the Ekins-Daukes I reference teaches Appellants' claimed structural interrelationship (i.e., that the tensile strained layers and the compressively strained layers making up a period have compositions such that each period "exerts substantially no shear force on a neighbouring structure"), claims 1, 18, 33 and 44 cannot be anticipated or rendered obvious by Ekins-Daukes I or any other reference.

As the burden is on the Patent Office to establish where or how a cited prior art reference anticipates or renders obvious a claimed combination of elements, the Examiner has simply failed to meet the burden of establishing a *prima facie* case of anticipation or obviousness in the Final Rejection. Clarification of where the Examiner believes Appellants' claimed interrelationship is disclosed in either Ekins-Daukes I or any other cited reference is respectfully requested.

(b) Ekins-Daukes I teaches that the average for <u>all</u> periods must be minimized, but not that <u>each</u> period should exert "substantially no shear force on a neighbouring structure"

Not only does the Ekins-Daukes I reference fail to teach that it is desirable that each period "exerts substantially no shear force on a neighbouring structure,"

but in teaching that it is only necessary that the average lattice parameter across the entire 20-period layer be a negligible quantity, Ekins-Daukes I essentially suggests that one can ignore shear forces created by individual periods and need only tailor the average shear force of the entire 20-period cycle.

The Court of Appeals for the Federal Circuit has consistently held that if a prior art reference teaches away from or would lead one of ordinary skill in the art away from applicant's claimed combination of elements, this reference does not support an obviousness rejection. Such is the case with Ekins-Daukes I, in that it suggests that one can ignore shear forces created by individual periods and only need take into account the average shear force created by the 20-period stack of elements.

Accordingly, Ekins-Daukes I teaches away from Appellants' claimed combination set out in independent claims 1, 18, 33 and 44.

(c) Freundlich '310 and '604, in suggesting limiting to 20 periods, teach away from the claimed invention

Freundlich '310 and Freundlich '604 also are believed to teach away from Appellants' claimed combination. As the Examiner admits, they have nothing to do with teaching the average "strain-balance approach" for the 20-period system (let alone the individual period characteristics which "exerts substantially no shear force on a neighbouring structure"). These references do not cure the deficit noted above with respect to the Ekins-Daukes I reference.

Moreover, the two Freundlich references merely suggest that as long as the number of periods is limited to 20 or less, the problem of dislocations and reduced solar cell efficiency is resolved. While in a preferred embodiment, Appellants' specification provides an example of a less than 20 period layer, there is certainly no limit, at least at the 20-period level, in creating a highly efficient solar cell. Because Freundlich '310 and '604 teach that the problem of dislocations is solved by limiting the number of periods and not by limiting the shear force applied to each period's neighboring structure, they would lead one of ordinary skill in the art away from Appellants' claimed combination of elements.

Because the two Freundlich patents teach away from the present invention, they cannot render obvious the independent claims.

(d) There is no reason or motivation for combining any of the prior art references

Moreover, as noted in the Discussion of the References, the Examiner has made conclusory statements that one of ordinary skill in the art would be "motivated" to combine the references, but has not provided any evidence or indication of how or why that person would be motivated to combine the references.

As noted above, Ekins-Daukes I suggests that the problem of solar cell dislocations can be aided by an average "strain-balance approach," and the

Feundlich references suggest that the same problem can be cured by limiting the number of periods to 20 or less. Because these references teach two different solutions to the problem, their combination would involve utilizing less than 20 periods and ensuring that the average "strain-balance" for the 20 periods was a negligible quantity. Thus, even the combination of the Ekins-Daukes I and Freundlich references would not teach or suggest having each period "exert substantially no shear force on a neighbouring structure."

Furthermore, in order to combine references, the burden is on the Patent Office to establish how or where there is some suggestion for the combination. Other than alleging that it would provide a beneficial result, the Examiner has failed to provide any rationale or evidence or record which would motivate one of ordinary skill in the art to combine these references. Again, this critical aspect of a rejection under §103 based upon a combination of references has been ignored by the Examiner.

IX. CONCLUSION

No reference cited by the Examiner in the Final Rejection teaches Appellants' claim limitation that each period "exerts substantially no shear force on a neighbouring structure" as set out in claims 1, 18, 33 and 44 (the equation of claim 44 sets out the same limitation in the equation). Ekins-Daukes I teaches away from Appellants' claimed combination, where each period is "strain-

balanced" with its neighboring structure and instead suggests that it is only necessary to guarantee that the average lattice parameter is strain-balanced. The Freundlich references teach away from any strain-balanced approach for correcting the problem of dislocations and suggests instead that one limit the structure to 20 or less periods. The Examiner has failed to provide any motivation for combining any of the three cited references and therefore fails to establish a *prima facie* case of obviousness.

Thus, and in view of the above, the rejection of claims 1-18, 20-27, 31-33 and 35-58 over the cited prior art is clearly in error and reversal thereof by this Honorable Board is respectfully requested.

Respectfully submitted,

NIXON & VANDERHYE P.C.

By: ______________________

Stanley C. Spooner
Reg. No. 27,393

SCS:kmm
Enclosures
Appendix A - Claims on Appeal

861773

APPENDIX A

Claims on Appeal

1. A photovoltaic device comprising:

a plurality of quantum wells and

a plurality of barriers, said barriers alternating with said quantum wells, one of said plurality of quantum wells and said plurality of barriers comprised of tensile strained layers and the other of said plurality of quantum wells and said plurality of barriers comprised of compressively strained layers, said tensile strained layers and said compressively strained layers having compositions such that a period of one tensile strained layer and one compressively strained layer exerts substantially no shear force on a neighbouring structure.

2. A photovoltaic device as claimed in claim 1, wherein said neighbouring structure is one of:

a further period of one tensile strained layer and one compressively strained layer;

a layer of arbitrary doping having a lattice constant; and

a substrate having a lattice constant.

3. A photovoltaic device as claimed in claim 1, being a crystalline photovoltaic device grown upon a substrate with a substrate lattice constant.

4. A photovoltaic device as claimed in claim 3, wherein at least one of said tensile strained layers or said compressively strained layers is a quantum well having a lattice constant not equal to said substrate lattice constant and having a Group III/V semiconductor composition with a bandgap lower than if said quantum well had a lattice constant equal to said substrate lattice constant.

5. A photovoltaic device as claimed in claim 3, wherein at least one of said tensile strained layers or said compressively strained layers is a barrier having a lattice constant not equal to said substrate lattice constant and a Group III/V semiconductor composition with a bandgap higher than if said barrier had a lattice constant equal to said substrate lattice constant.

6. A photovoltaic device as claimed in claim 1, wherein said multiple quantum well portion is formed of alternating quantum well layers and barrier layers having a Group III/V semiconductor composition, wherein a period of one quantum well layer and one quantum barrier layer contains at least four different elements and has an average lattice constant substantially matching a neighbouring structure lattice constant.

7. A photovoltaic device as claimed in claim 4, wherein said substrate is InP and said compressively strained layer is $In_xGa_{1-x}As$, where $x>0.53$.

8. A photovoltaic device as claimed in claim 5, wherein said substrate is InP and said tensile strained layer is $In_xGa_{1-x}As_{1-y}P_y$, where y>0.

9. A photovoltaic device as claimed in claim 8, wherein y=1 such that said tensile strained layer is GaInP.

10. A photovoltaic device as claimed in claim 3, wherein said substrate is InP and said multiple quantum well portion is formed of layers of $Al_xGa_{1-x}As_ySb_{1-y}$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$.

11. A photovoltaic device as claimed in claim 3, wherein said substrate is GaSb and said multiple quantum well portion is formed of layers of $In_xGa_{1-x}As_ySb_{1-y}$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$.

12. A photovoltaic device as claimed in claim 3, wherein said substrate is GaAs.

13. A photovoltaic device as claimed in claim 12, wherein said multiple quantum well portion is formed of layers of $In_xGa_{1-x}As_yP_{1-y}$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$.

14. A photovoltaic device as claimed in claim 1, wherein said multiple quantum well portion is formed upon a virtual substrate composed of a strain relaxed buffer layer having a virtual substrate lattice constant different from a substrate lattice constant of an underlying substrate.

15. A photovoltaic device as claimed in claim 14, wherein said virtual substrate is $InP_{1-y}As_y$, where $0<y<1$, and said substrate is InP.

16. A photovoltaic device as claimed in claim 1, wherein said photovoltaic device is a thermophotovoltaic device.

17. A photovoltaic device as claimed in claim 1, wherein said quantum wells have a bandgap substantially equal to or less than 0.73eV

18. A photovoltaic device having a multiple well quantum portion formed upon a virtual substrate having a virtual substrate lattice constant different than a substrate lattice constant of an underlying substrate, wherein said virtual substrate is $InP_{1-x}As_x$, where $0<x<1$, and said substrate is InP, wherein said multiple quantum well portion is formed with alternating tensile strained layers and compressively strained layers, said tensile strained layers and said compressively strained layers having compositions such that a period of one tensile strained layer and one compressively strained layer exerts substantially no shear force on a neighbouring structure.

20. A photovoltaic device as claimed in claim 18, wherein said neighbouring structure is one of:

a further period of one tensile strained layer and one compressively strained layer;

a layer of arbitrary doping having the same lattice constant as said virtual substrate; and

said virtual substrate.

21. A photovoltaic device as claimed in claim 20, wherein at least one of said tensile strained layers or said compressively strained layers is a quantum well having a lattice constant not equal to said substrate lattice constant and a Group III/V semiconductor composition with a bandgap lower than if said quantum well had a lattice constant equal to said substrate lattice constant.

22. A photovoltaic device as claimed in claim 20, wherein at least one of said tensile strained layers or said compressively strained layers is a barrier having a lattice constant not equal to said substrate lattice constant and a Group III/V semiconductor composition with a bandgap higher than if said barrier had a lattice constant equal to said substrate lattice constant.

23. A photovoltaic device as claimed in claim 18, wherein said multiple quantum well portion is formed of alternating quantum well layers and barrier layers having a Group III/V semiconductor composition, wherein a period of one quantum well layer and one quantum barrier layer contains at least four different elements and has an average lattice constant substantially matching a neighbouring structure lattice constant.

24. A photovoltaic device as claimed in claim 21, wherein said substrate is InP and said compressively strained layer is $In_xGa_{1-x}As$, where x is larger than z of $In_zGa_{1-z}As$ which is lattice-matched to the virtual substrate.

25. A photovoltaic device as claimed in claim 23, wherein said substrate is InP and said tensile strained layer is $In_xGa_{1-x}As_{1-y}P_y$, where $y>0$.

26. A photovoltaic device as claimed in claim 25, wherein $y=1$ such that said tensile strained layer is GaInP or wherein $x=1$ such that said tensile strained layer is InAsP.

27. A photovoltaic device as claimed in claim 18, wherein said substrate is InP and said multiple quantum well portion is formed of layers of $Al_xGa_{1-x}As_ySb_{1-y}$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$.

31. A photovoltaic device as claimed in claim 18, wherein said photovoltaic device is a thermophotovoltaic device.

32. A photovoltaic device as claimed in claim 18, wherein said quantum wells have a bandgap substantially equal to or less than 0.73eV

33. A photovoltaic device having a multiple quantum well portion formed of strained alternating quantum well layers of $In_xGa_{1-x}As$, where x>0.53, and barrier layers of $Ga_yIn_{1-y}P$, where y>0, wherein said multiple quantum well portion is formed with alternating tensile strained layers and compressively strained layers, said tensile strained layers and said compressively strained layers having compositions such that a period of one tensile strained layer and one compressively strained layer exerts substantially no shear force on a neighbouring structure.

35. A photovoltaic device as claimed in claim 33, wherein said neighbouring structure is one of:

a further period of one tensile strained layer and one compressively strained layer;

a layer of arbitrary doping having a lattice constant; and

a substrate having a lattice constant.

36. A photovoltaic device as claimed in claim 33, being a crystalline photovoltaic device grown upon a substrate layer with a substrate lattice constant.

37. A photovoltaic device as claimed in claim 36, wherein said substrate is InP.

38. A photovoltaic device as claimed in claim 33, wherein said multiple quantum well portion is formed upon a virtual substrate composed of a strain relaxed buffer layer having a virtual substrate lattice constant different from a substrate lattice constant of an underlying substrate.

39. A photovoltaic device as claimed in claim 38, wherein said virtual substrate is $InP_{1-y}As_y$, where $0<y<1$, and said substrate is InP.

40. A photovoltaic device as claimed in claim 33, wherein said photovoltaic device is a thermophotovoltaic device.

41. A photovoltaic device as claimed in claim 33, wherein said quantum wells have a bandgap substantially equal to or less than 0.73eV.

42. A photovoltaic device as claimed in claim 1, wherein said quantum wells comprise said compressively strained layers.

43. A photovoltaic device as claimed in claim 1, wherein said barriers comprises said tensile strained layers.

44. A photovoltaic device having a substrate with a substrate lattice constant a_0 and multiple quantum well portion with alternating tensile strained layers with a lattice constant a_1, a thickness t_1 and elastic stiffness coefficients C_{11} and C_{12} and compressively strained layers with a lattice constant a_2, a thickness t_2 and elastic stiffness coefficients C_{21} and C_{22}, said tensile strained layers and said compressively strained layers having compositions such that a period of one tensile strained layer and one compressively strained layer substantially meets the conditions:

$$\varepsilon_1 t_1 A_1 a_2 + \varepsilon_2 t_2 A_2 a_1 = 0; and$$

$$a_0 = \frac{t_1 A_1 a_1 a_2^2 + t_2 A_2 a_2 a_1^2}{t_1 A_1 a_2^2 + t_2 A_2 a_1^2};$$

where

$$A_1 = C_{11} + C_{12} - \frac{2C_{12}^2}{C_{11}};$$

$$A_2 = C_{21} + C_{22} - \frac{2C_{22}^2}{C_{21}};$$

$$\varepsilon_1 = \frac{a_0 - a_1}{a_1}; and$$

$$\varepsilon_2 = \frac{a_0 - a_2}{a_2}$$

45. A photovoltaic device as claimed in claim 44, wherein at least one of said tensile strained layers or said compressively strained layers is a quantum well having a

Group III/V semiconductor composition with a bandgap lower than if said quantum well had a lattice constant equal to said substrate lattice constant.

46. A photovoltaic device as claimed in claim 44, wherein at least one of said tensile strained layers or said compressively strained layers is a barrier having a Group III/V semiconductor composition with a bandgap higher than if said barrier had a lattice constant equal to said substrate lattice constant.

47. A photovoltaic device as claimed in claim 44, wherein said multiple quantum well portion is formed of alternating quantum well layers and barrier layers having a Group III/V semiconductor composition, wherein a period of one quantum well layer and one quantum barrier layer contains at least four different elements and has an average lattice constant substantially matching a neighbouring structure lattice constant.

48. A photovoltaic device as claimed in claim 45, wherein said substrate is InP and said compressively strained layer is $In_xGa_{1-x}As$, where $x>0.53$.

49. A photovoltaic device as claimed in claim 46, wherein said substrate is InP and said tensile strained layer is $In_xGa_{1-x}As_{1-y}P_y$, where $y>0$.

50. A photovoltaic device as claimed in claim 49, wherein y=1 such that said tensile strained layer is GaInP.

51. A photovoltaic device as claimed in claim 44, wherein said substrate is InP and said multiple quantum well portion is formed of layers of $Al_xGa_{1-x}As_ySb_{1-y}$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$.

52. A photovoltaic device as claimed in claim 44, wherein said substrate is GaSb and said multiple quantum well portion is formed of layers of $In_xGa_{1-x}As_ySb_{1-y}$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$.

53. A photovoltaic device as claimed in claim 44, wherein said substrate is GaAs.

54. A photovoltaic device as claimed in claim 53, wherein said multiple quantum well portion is formed of layers of $In_xGa_{1-x}As_yP_{1-y}$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$.

55. A photovoltaic device as claimed in claim 44, wherein said substrate is a virtual substrate composed of a strain relaxed buffer layer having a virtual substrate lattice constant different from a substrate lattice constant of an underlying substrate.

56. A photovoltaic device as claimed in claim 55, wherein said virtual substrate is $InP_{1-y}As_y$, where $0 < y < 1$, and said substrate is InP.

57. A photovoltaic device as claimed in claim 44, wherein said photovoltaic device is a thermophotovoltaic device.

58. A photovoltaic device as claimed in claim 44, wherein said quantum wells have a bandgap substantially equal to or less than 0.73eV.